Shield block development of ITER Module 18

PFC eMeeting

November 02, 2005

D.L. Youchison

T.J. Tanaka

J.H. Bullock

M.A. Ulrickson

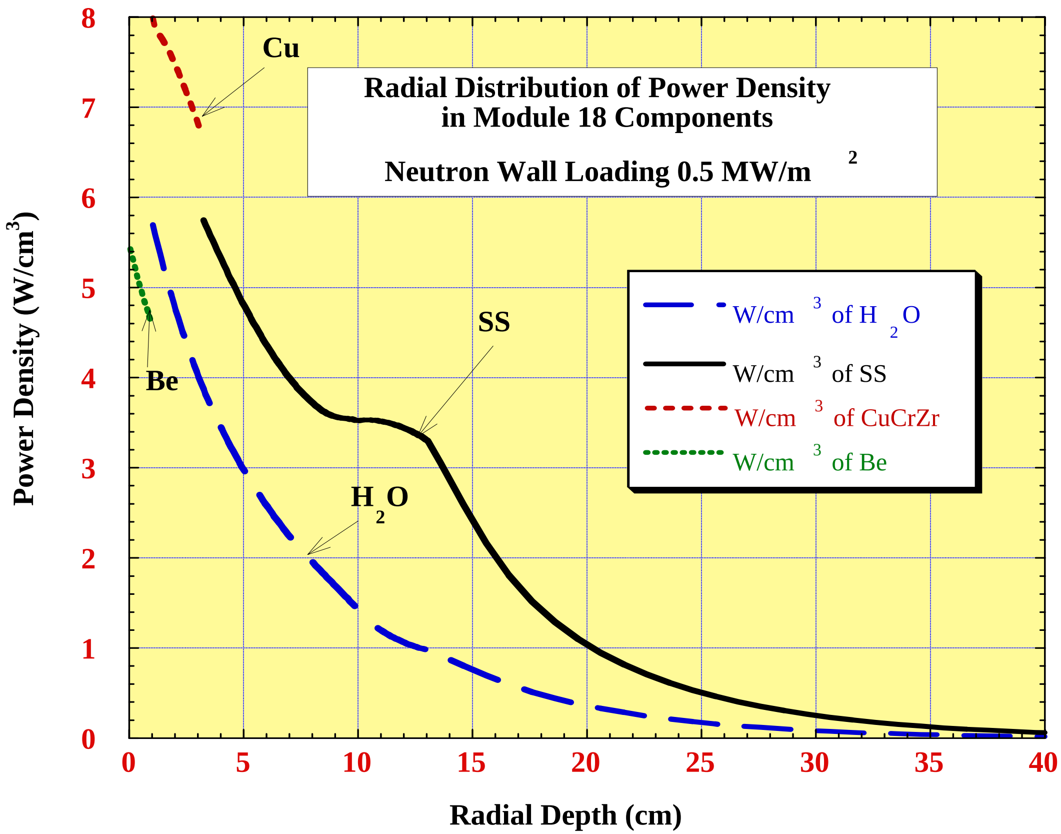
Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Issues with IT Shield Design

- Minimum required heat transfer coefficient for “front header” with a top plate of 20mm would be about 2000 W/m^2K (using Sawan’s calculation)
- Chinese report calculation of heat transfer coefficient with no flow guide~1400 W/m^2K, and with flow guide 4270 W/m^2K
- But there were corners of the front reservoir which may not have enough flow velocity
- Dong Won Lee (KAERI) also shows that a different design is needed and has proposed a T shape that also improves flow velocity

M. Sawan 1D nuclear heating data



Flat area of SS power density curve corresponds to 20 mm thick cover plate of the IT baseline design.
The power density here was assumed for the front side of the upside-down reservoir idea.

In this 1D calculation the heating distribution is calculated with a SS-water mix in the majority of the module

Sandia National Laboratories

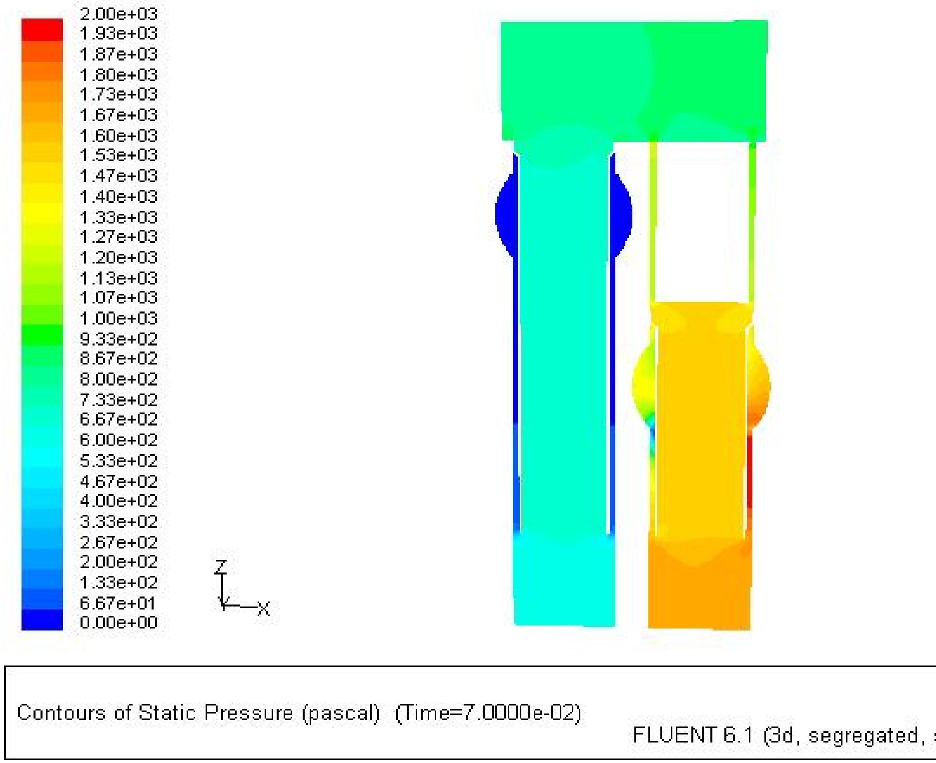
IT design on Module 18

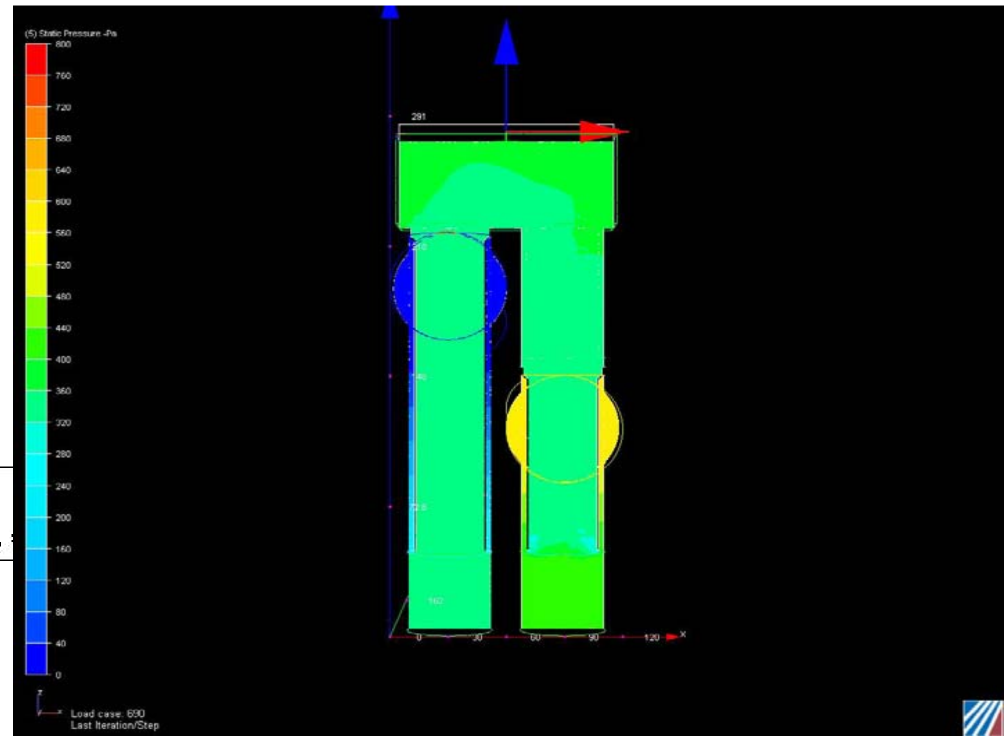
- Our radial holes are 30 mm dia as this module is narrower than modules 2-6
- 20 radial holes distributed vertically
- Flow out of each hole into front reservoir is 0.044kg/s (1.76kg/s / 40 holes)
- Average heat transfer coefficient is 5500W/m^2K for the front surface, but it varies a lot depending on position

Sandia National Laboratories

Fluent & CFDesign (IT design)

This calculation was difficult in the region of small clearance and may need refinement.





45mm dia radial holes,
2.5 mm insert clearance,
60 mm dia headers

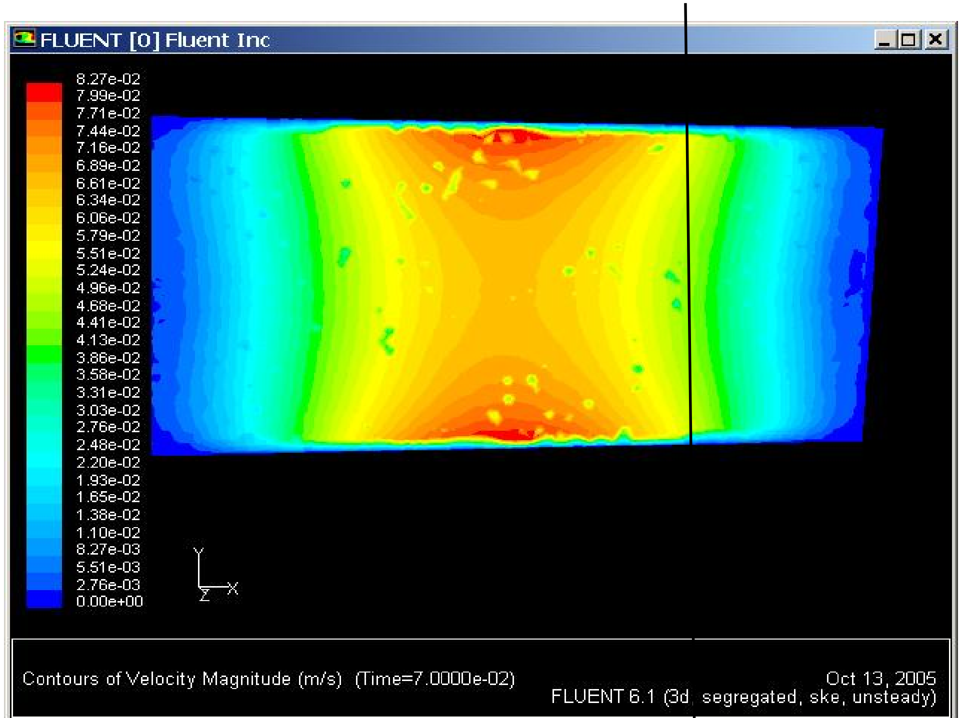
Sandia National Laboratories

Flow velocity for Original IT design on top surface for module 18

Top surface view

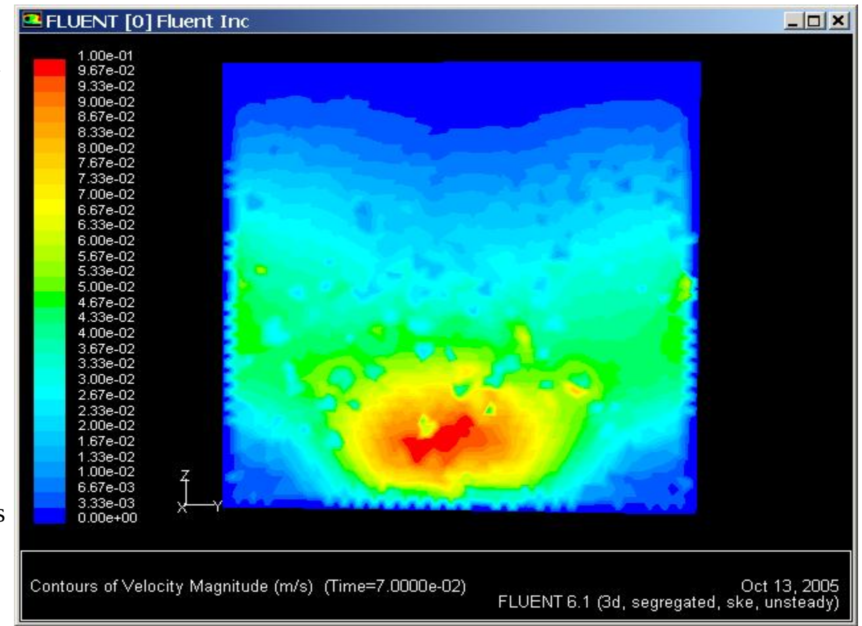
Short-side view

.083



0 m/s

0.1



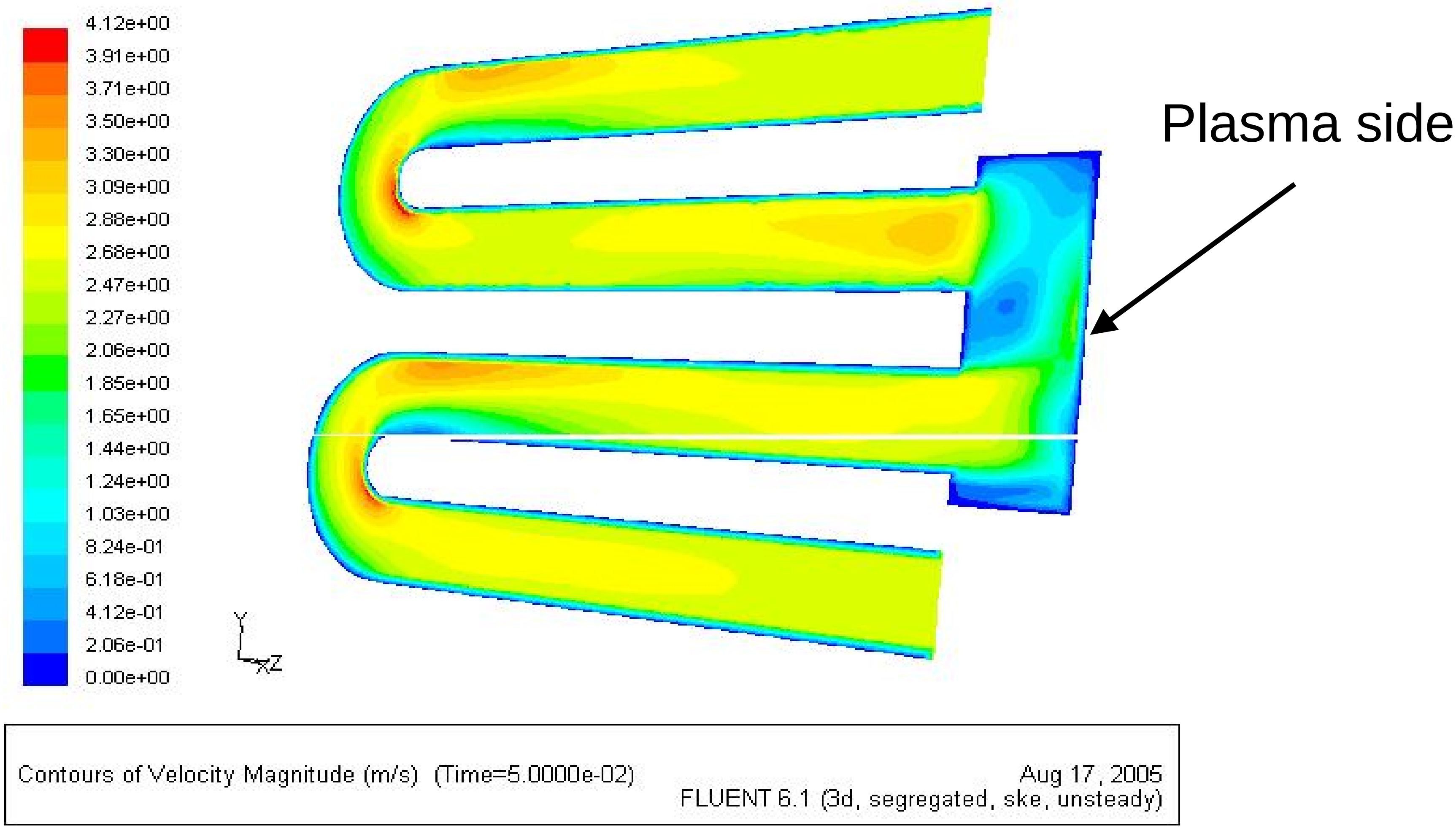
0 m/s

Without a driver, the flow through the top reservoir is about .06 m/s
In the outer corners, the flow is not high enough

Hydraulic analysis

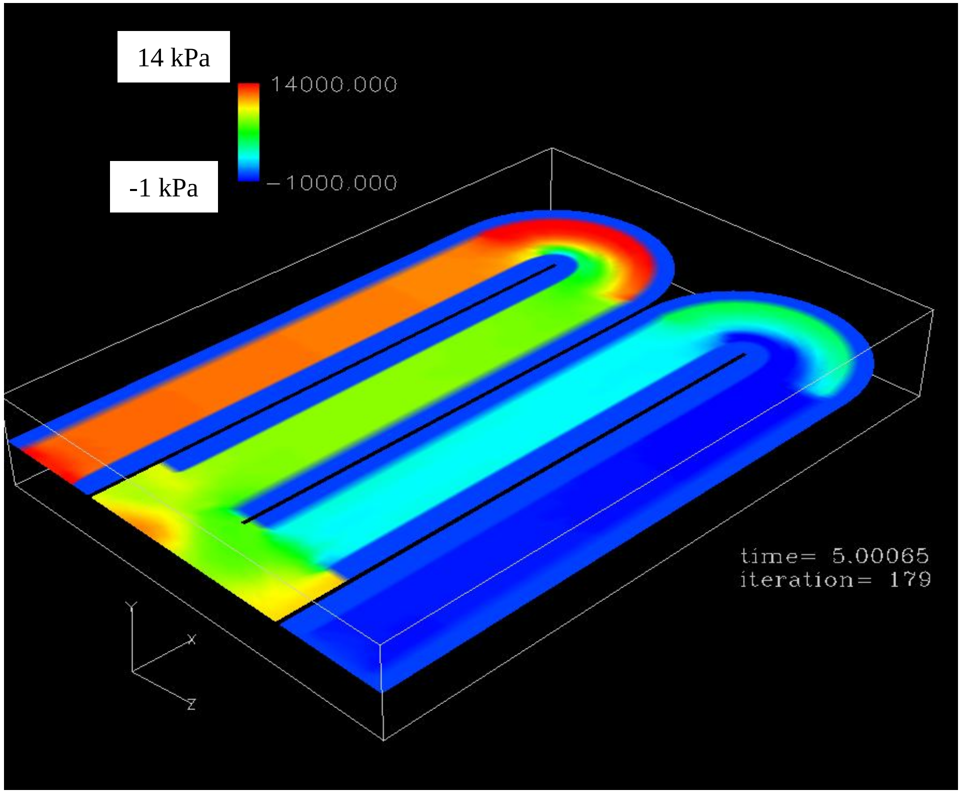
- Three computer codes are compared
  - Fluent
    - Powerful and popular code
    - Finite volume
    - Geometry import/translation required
  - CFDesign
    - Finite element
    - Direct CATIA input
  - CFD2000
    - Finite volume
    - Takes longer than CFDesign
    - No geometry imports

Our original design with reservoir in the back had problems of slow velocity in the hottest region



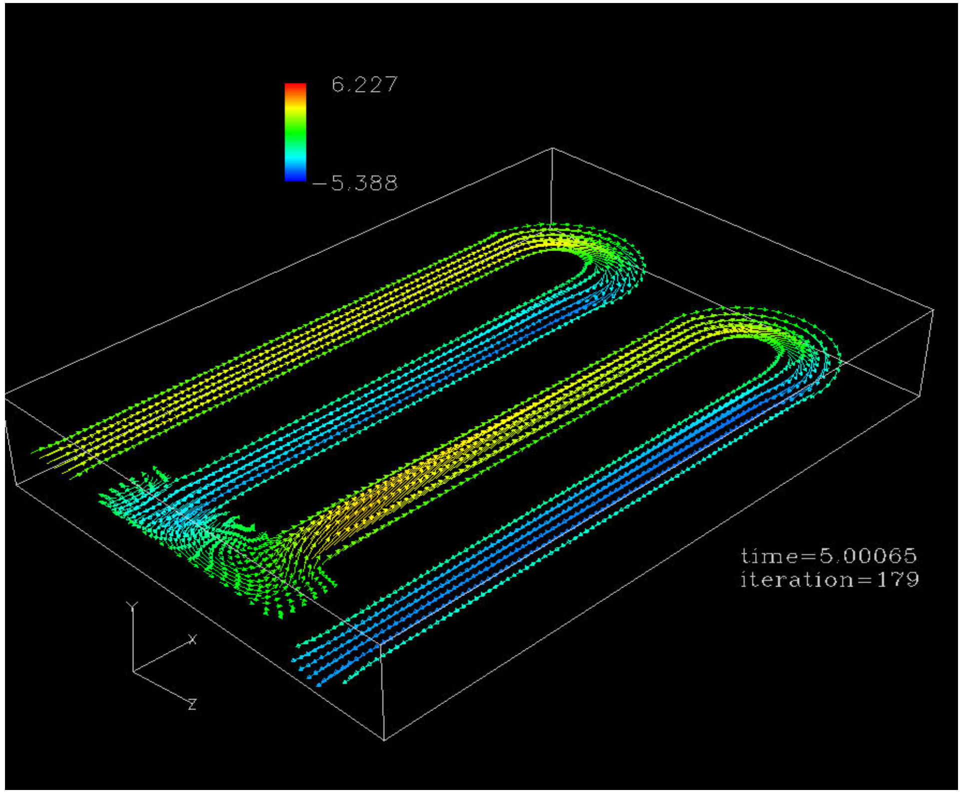
This shows the analysis of the velocity using Fluent

CFD-2000 Results US design



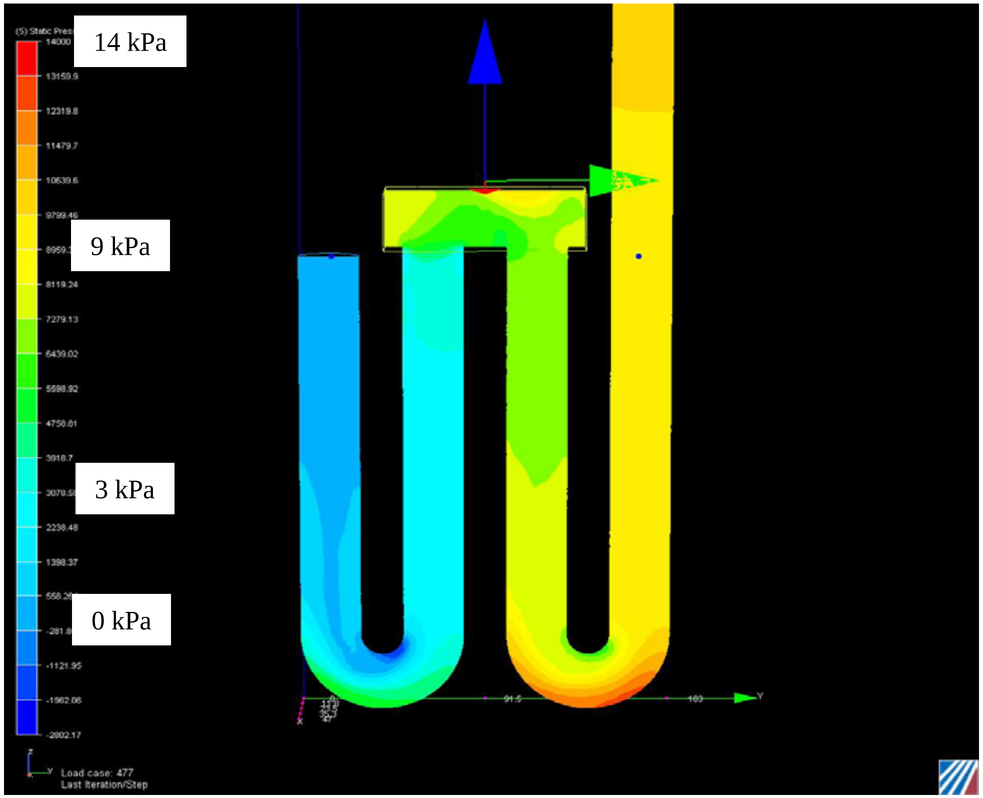
Static pressure

Velocity (m/s)



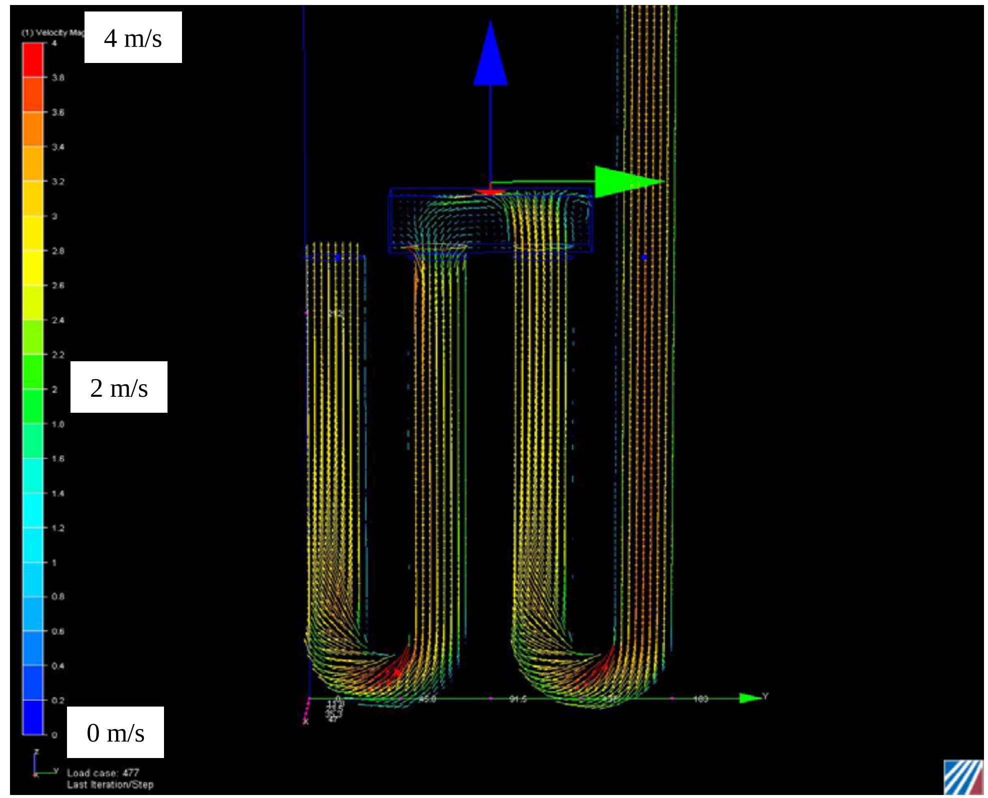
Sandia National Laboratories

CFdesign Results



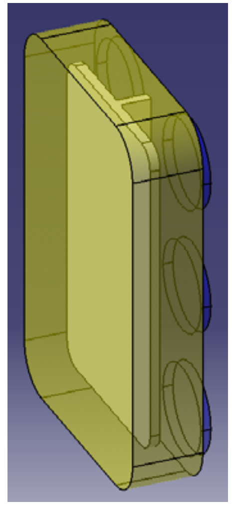
Static pressure

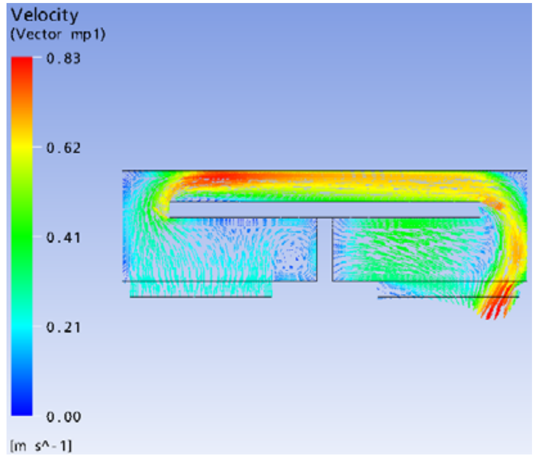
Velocity



New Idea for flow

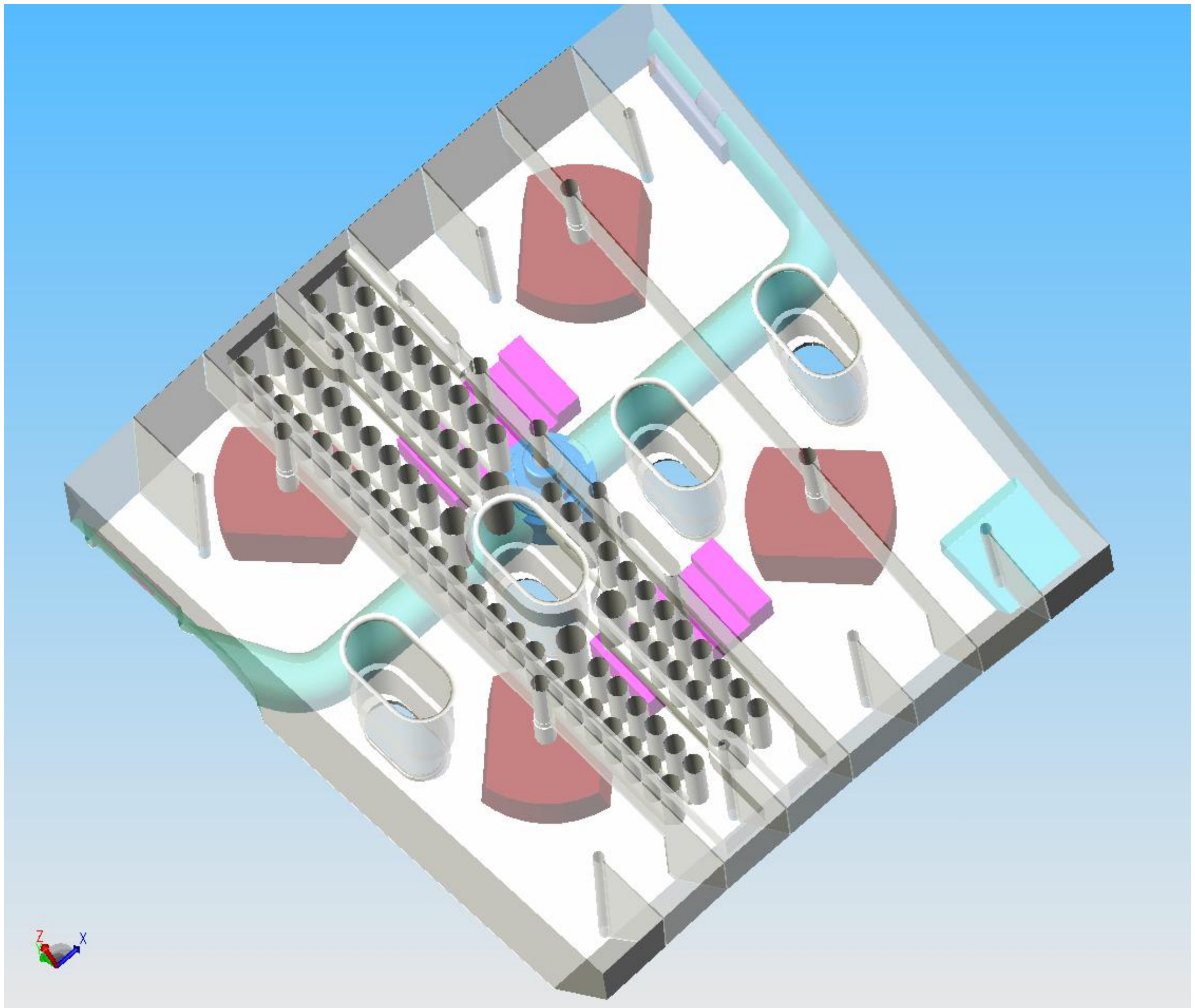
- Explore use of Tee divertor vane in shield block reservoir as proposed by Koreans
- Change loop depth so that most material on plasma face is within 10 mm of cooling loop
- Loops are mostly in series, but break out in a few parallel paths
- 23 radial holes, 30-mm DIA
- No flow annuli in the loops – use orifice plate
- Smallest hydraulic distance is 15 mm





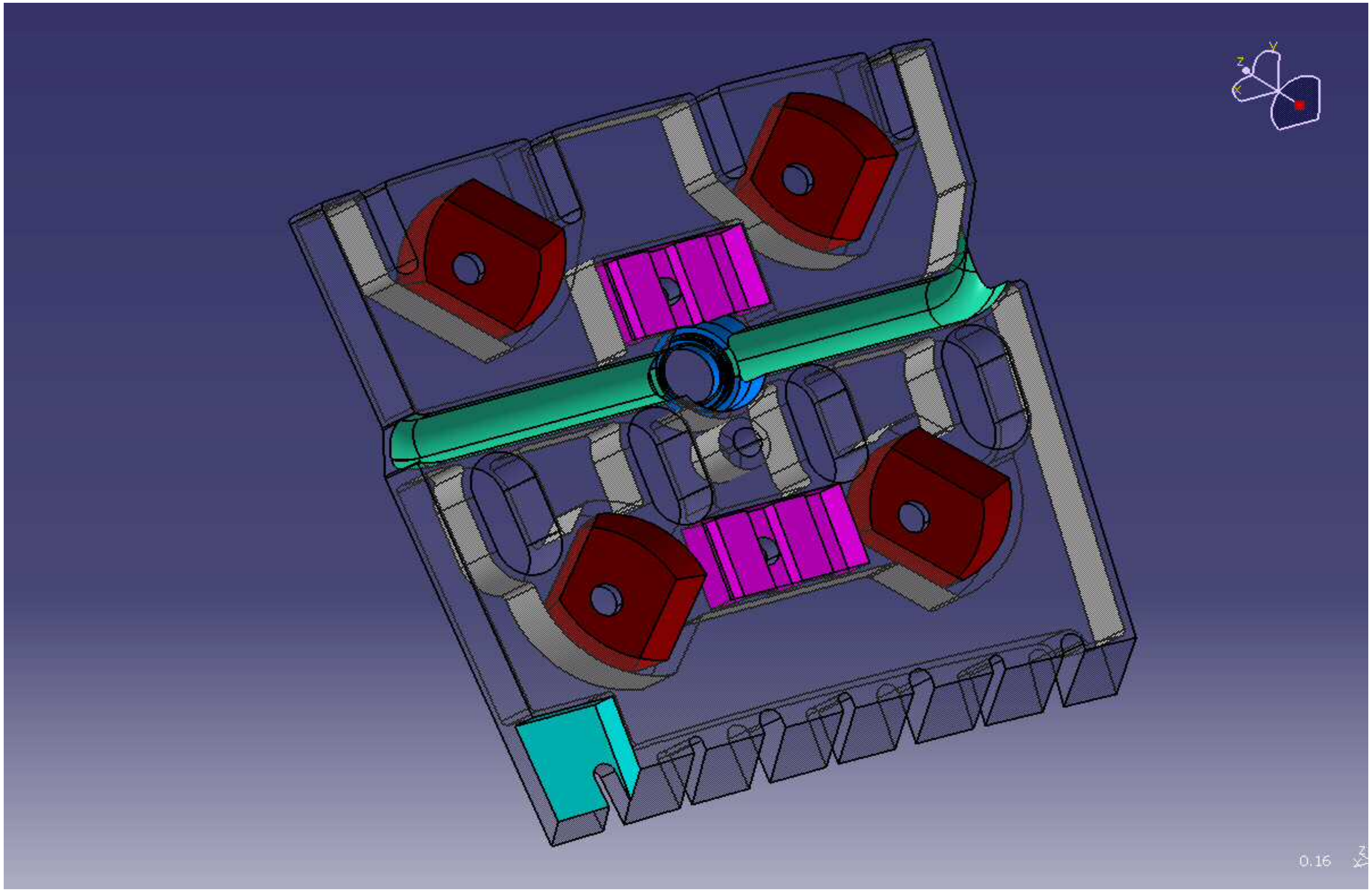
Sandia National Laboratories

How the top surface will look



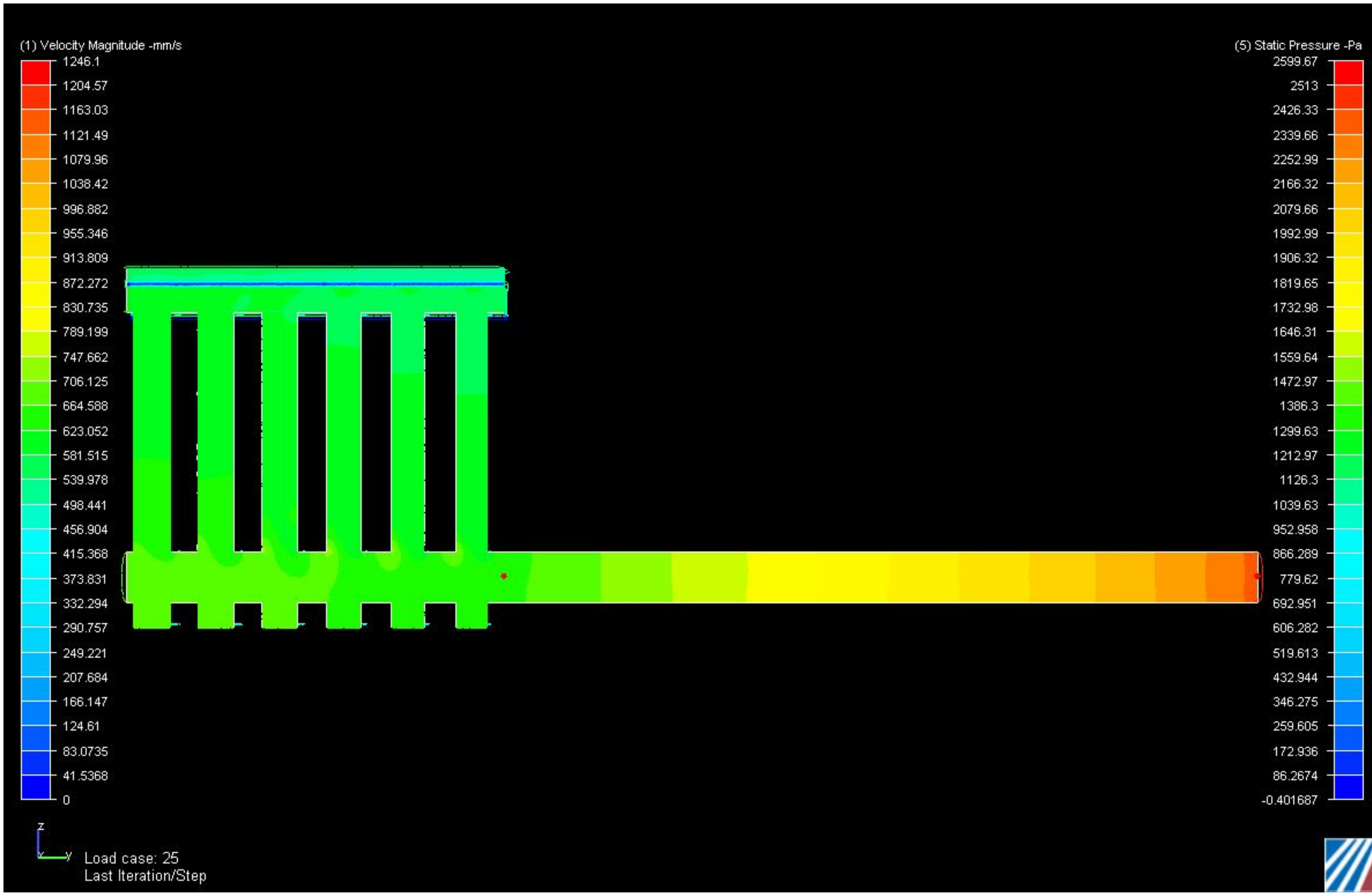
Sandia National Laboratories

Back piece



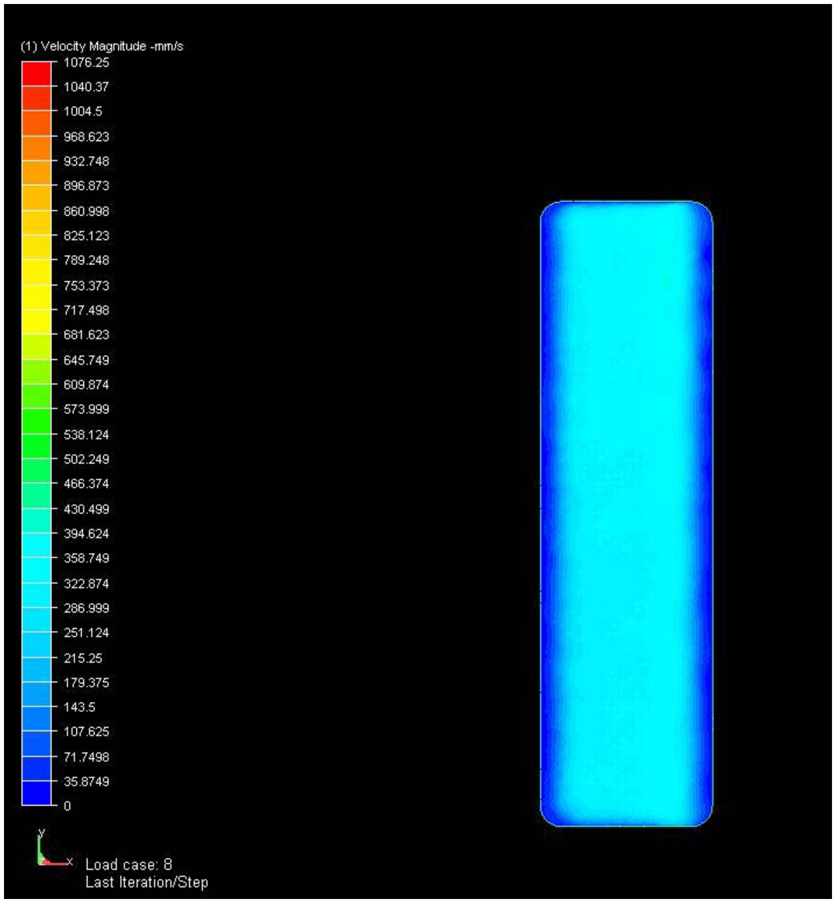
Sandia National Laboratories

Orificing required to obtain more uniform flow distribution.

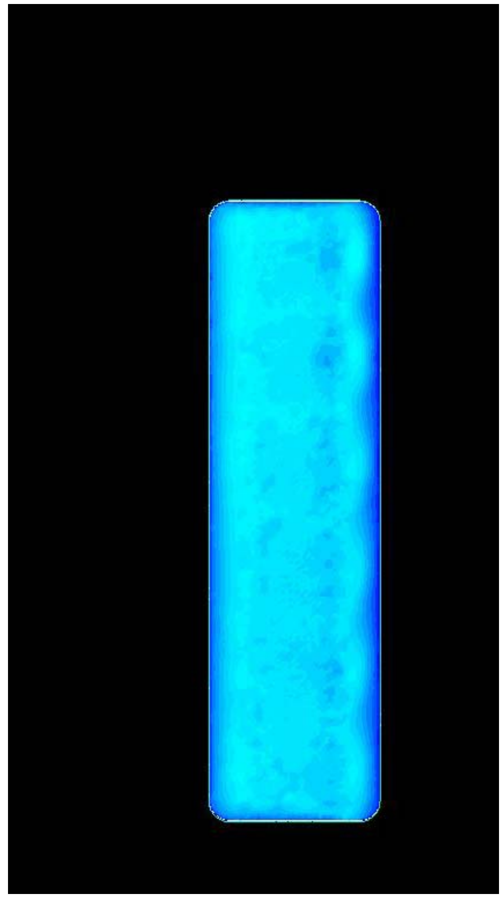


Velocity distributions in reservoir

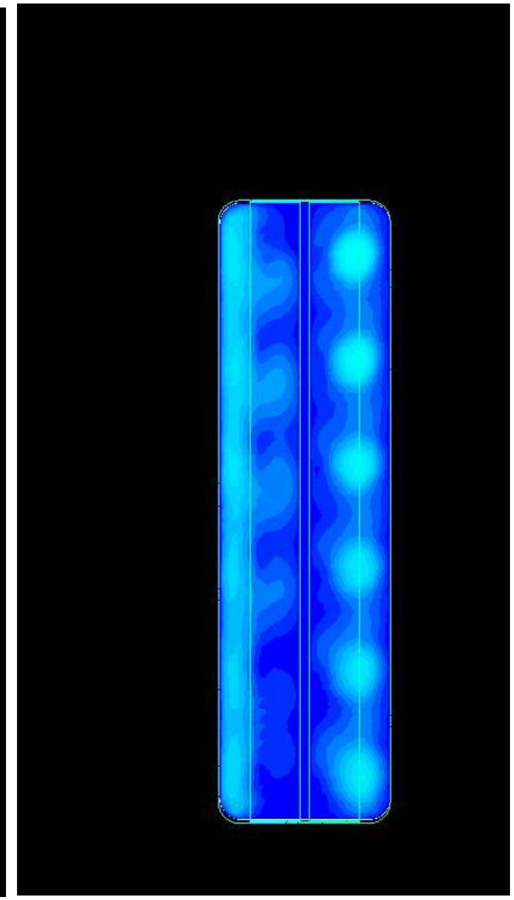
top



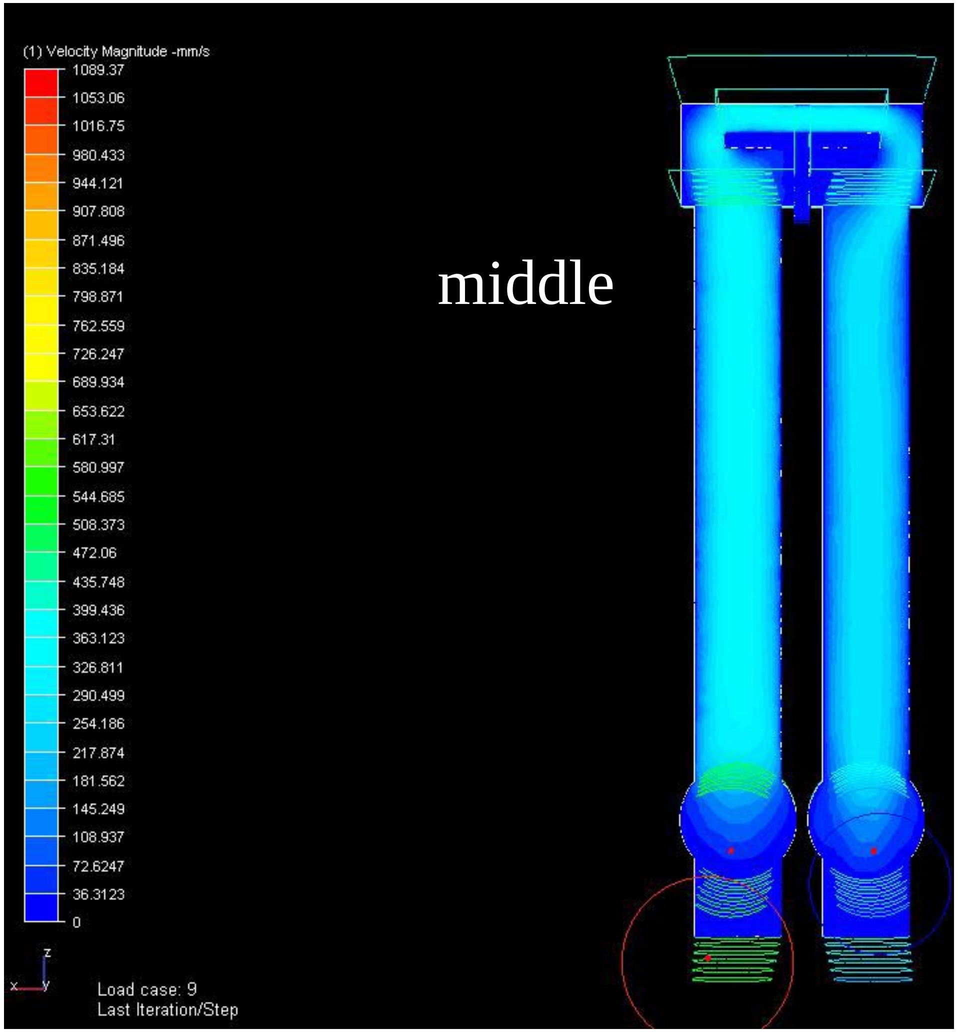
vane level

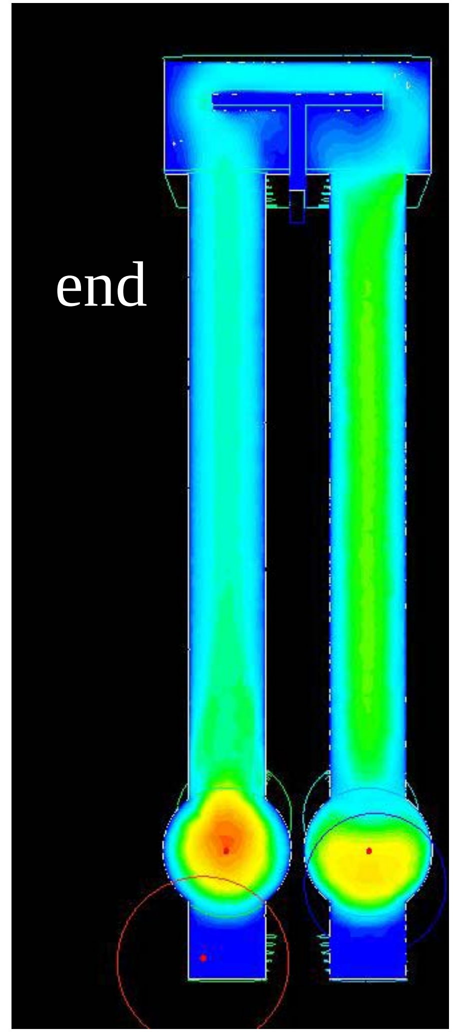


bottom



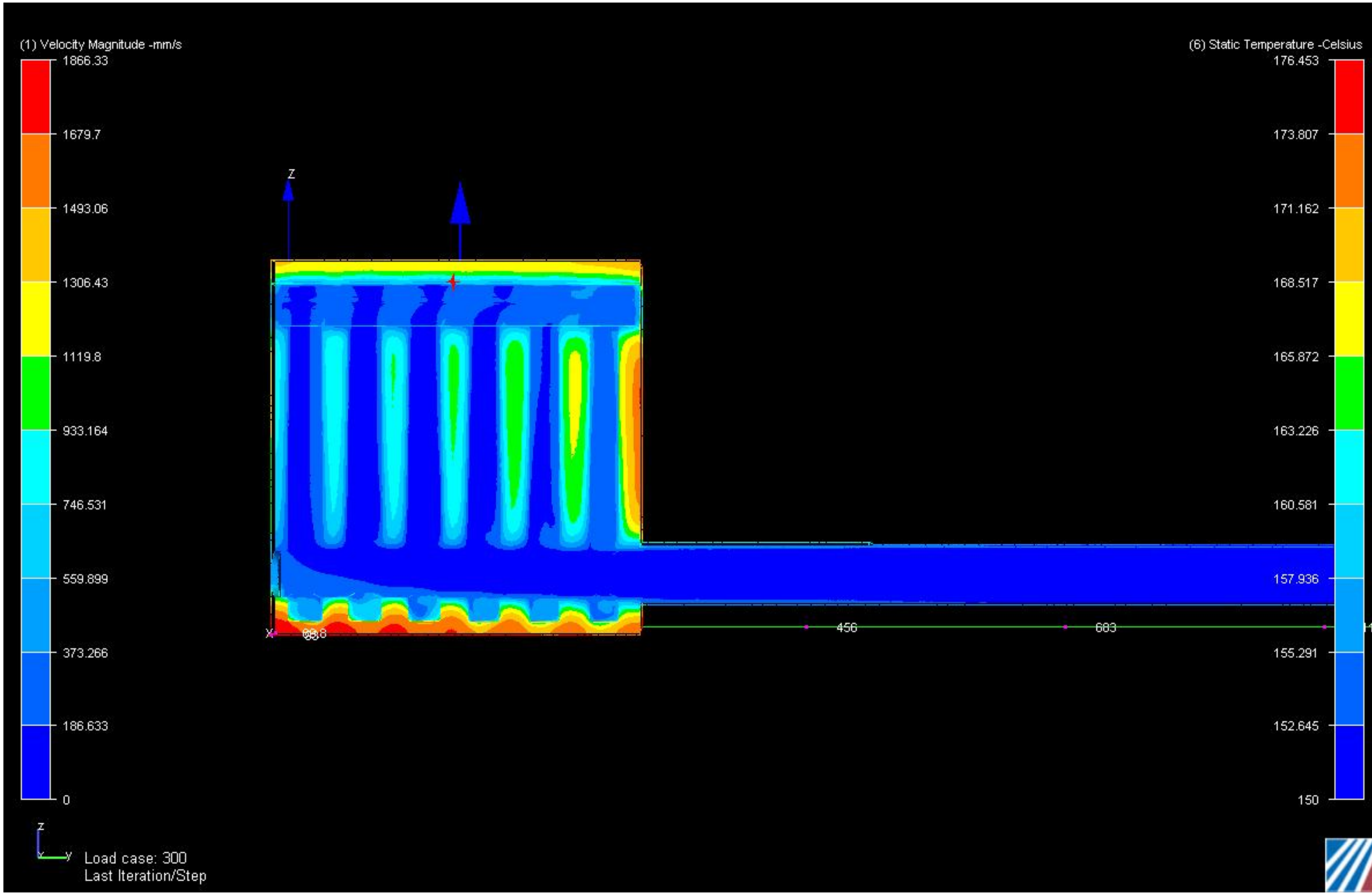
Velocity distributions (con't)



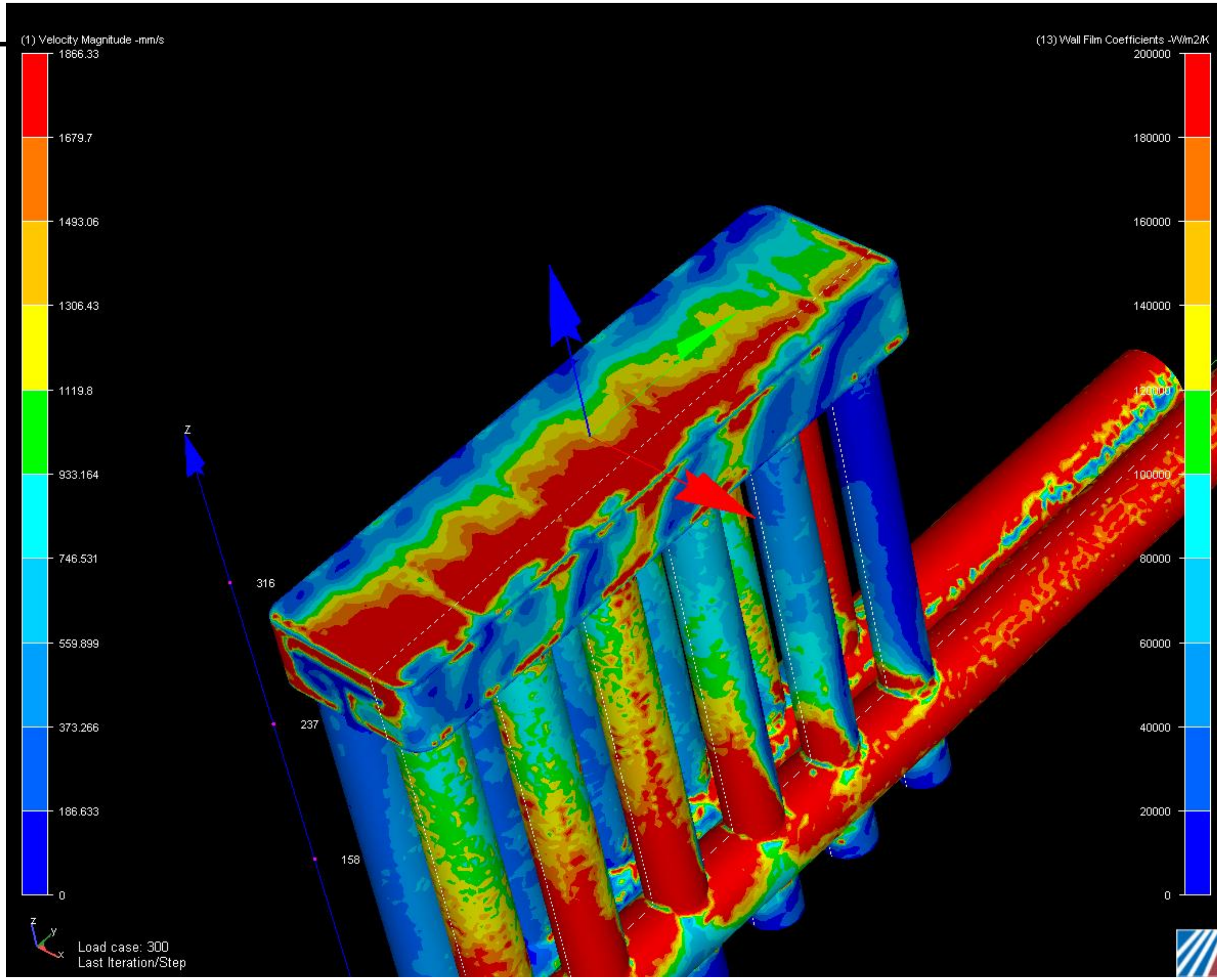


Sandia National Laboratories

Temperature distribution – uniform q=3.6 W/cm^3

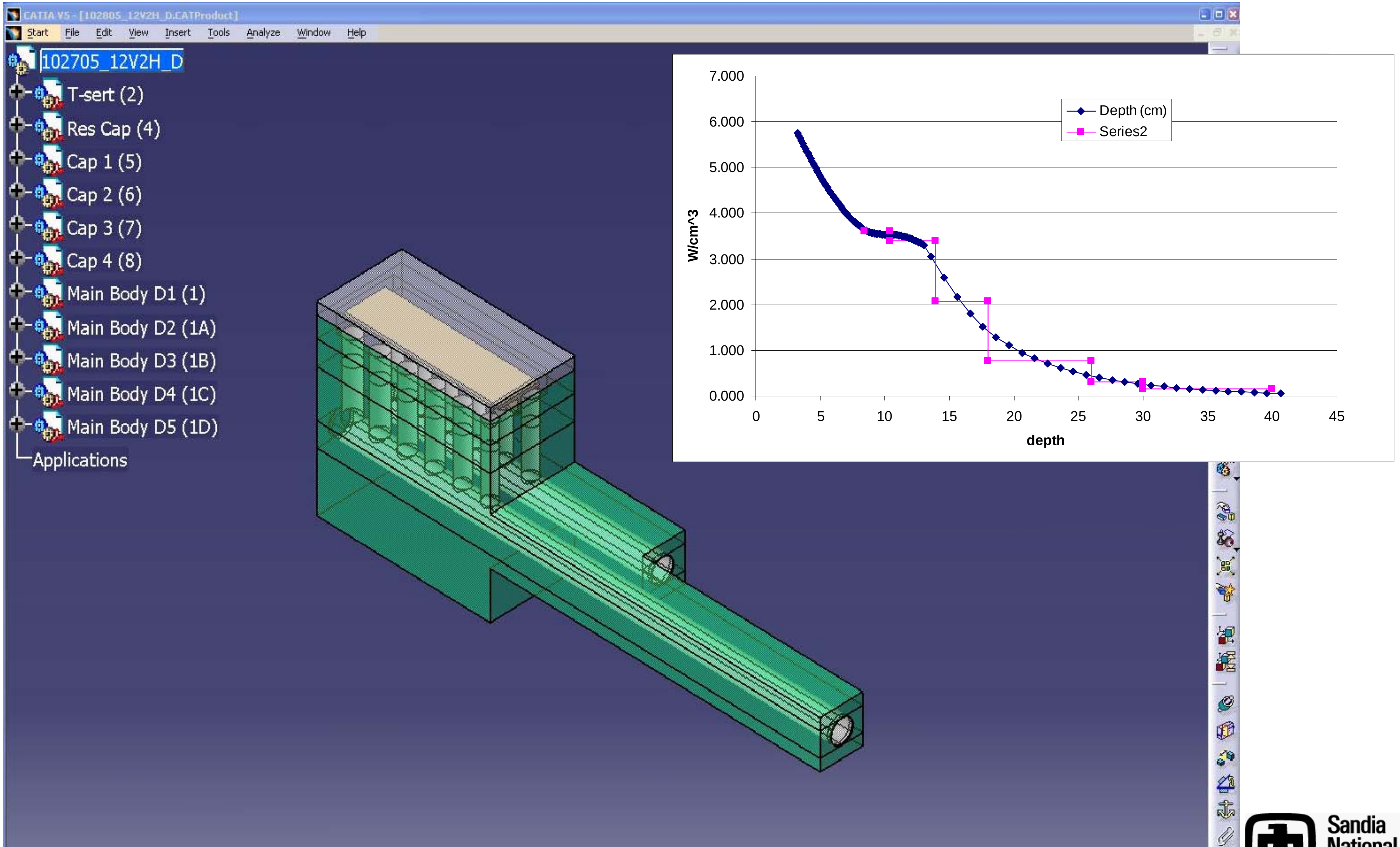


Wall film coefficient, h



Sandia National Laboratories

Zoned CFdesign Model



Conclusions

- US design is evolving
- Separate design from manufacturing technique
- US favors casting, Int'l team set on forging & machining
- Prefer tee divertor vane concept with orificing rather than complicated flow annuli used in IT Module 4
- CFD heat transfer with directly coupled ABAQUS thermal stress analysis to be completed by end of 2005.